



Original communication

The value of radius bone in prediction of sex and height in the Iranian population

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ABSTRACT

Objective: Measurement of anthropometric parameters of long bones can be applied in sex determination and height prediction. The aim of this study was to investigate the value of length of the radius in forensic identification.

Materials and methods: Cross-sectional analysis of anthropometric parameters of the radius was done by Legal Medicine Organization of Tehran, Iran studying fresh cadavers of Iranian population during 2009 and 2010.

Results: This study surveyed length of radius of 106 fresh Iranian cadavers, 61 men and 45 women, in the age range of 10–85 years old. The study showed that genders can be distinguished using the length of radius with a sensitivity of 83% and specificity of 96%. Using the regression test, there was significant relation between the height of persons and the length of radius bone. The equations were obtained to estimate the height of the individuals on the basis of radius bone length in different age groups, with an exception in females of 40–64 Years old.

Conclusion: In the cases of fresh cadavers, by using the length of radius, we could be able to determine the length of height and gender with high confidence.

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1. Introduction

The cadavers delivered to the forensic medicine in order to determine their identity are not always intact and unharmed; rather, at times the only thing is the skeletal remains or even decomposed & amputated body fragments. This can be due to plane crashes, natural disasters, explosions and etc. When we have an incomplete skeleton, the measurement of length of long bones such as radius could be as a proper guide for selection of an equation for evaluation of height and prediction of gender.^{1–3} There are a few studies conducted on radius in the other countries,^{4–6} but this fact that the race could effect on the factors of personal identity needs more studies to reveal it more clearly. Thus, this study was

conducted in Iran, on the basis of the effect of race on the anthropometric dimensions of different bones.

2. Material and methods

This study was performed on 106 cadavers delivered to the Autopsy Hall of the Legal Medicine of Iran (LMO) between 2009 and 2010. All of the cadavers had an intact and unharmed left radius along with the rigor mortis. The anonymous cadavers, severe burning and coaly, skeleton, advanced post mortem changes, history of fracture in spinal vertebrae, radius and lower extremities were excluded.

After obtaining the written consent from the first relationship to the cadavers, the naked cadavers put in supine position on the autopsy bed and the length between vertex and heel was measured by a strip meter (with 10 mm precision); consequently, after making a cross incision on the skin of forearm and wrist we removed the soft tissue and exposed to the adjacent joints, the maximum length of radius and ulna measured by a graduated set

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Table 1
Frequency of both gender according to age groups.

Sex	Female		Male		Total	
	Number	Percent	Number	Percent	Number	Percent
Age group (yr)						
<20	9	8.49	11	10.37	20	18.9
20–39	16	15.09	24	22.64	40	37.7
40–64	12	11.32	19	17.92	31	29.2
≥65	8	7.54	7	6.60	15	14.2
Total	45	42.45	61	57.54	106	100

square (with the accuracy of 1 mm). Finally the skin and joints were reconstructed.

Statistical analysis of our data was performed by using SPSS 13 software and descriptive and analytical tests. A level of $P < 0.05$ was considered significant.

3. Results

In this study among 106 cadavers, 61 (57.5%) were male, 45 (42.5%) were female. The cadavers of both genders were divided into 4 age groups:

- I Less than 20 years old
- II 20–39 years old
- III 40–64 years old
- IV 65 and over 65 years old

The frequency of population in each sex according to the different age groups was indicated in the Table 1.

The mean age of individuals was 39.19 (10–85) years old. The mean age of female and male was 41.27 (10–85) and 37.66 (12–78); respectively.

The comparison of the mean, standard deviation, the minimum and maximum of the height length and the length of radius in different age groups according to sex were indicated in Table 2 & Table 3.

In order to statistical analysis, firstly the normal distribution of varieties was considered by Lilliefors Kolmogorov Smirnov test, the height of decedents and length of radius bones had normal distribution among the 4 age groups; then *t*-test was used for analysis, the mean of height and length of radius in males were meaningfully higher than females ($p = 0.00$).

According to the statistically significant difference between the length of radius bone in males and females in different age groups, the average mean of the length of radius bone in both sexes was considered as demarking point (d.p), therefore on the basis of the ROC test, the rate of sensitivity and specificity of d.p in order to separate the genders from each other in different age groups were obtained (Table 4).

On the basis of the above table, by using the length of radius bone as 22.7 cm, with a sensitivity of 83% and specificity of 96%, it would be possible for us to recognize between male and female.

According to the regression test, there was a statistically significant ($p = 0.00$) relation between the height of persons and the length of radius bone. The following equation was obtained to estimate the height on the basis of radius bone length.

$$\text{Height(cm)} = 74.79 + [3.91 \times \text{the length of radius (cm)}]$$

On the basis of the above test, the reported equations in Table 5 for estimation the height by using radius in each gender and different age groups were obtained (Table 5).

In this study the ratio of length of radius to ulna was calculated, the mean of this ratio was 0.970 with the standard deviation of 0.035 in male, and 0.969 with standard deviation of 0.037 in female. Therefore, there was no significant statistical difference for this ratio between males and females ($P = 0.78$). There was also no significant difference for this ratio among the different age groups ($P = 0.155$).

The comparison of the mean, standard deviation, the minimum and maximum of the ratio of length of radius to ulna in different age and sex groups were indicated in Table 6.

4. Discussion

Using long bones of upper limbs to identify the personal identity such as estimation of height and sex have been considered in different studies.^{2,4–6}

This study was performed to review the relation between the length of radius and the height, and the precision of bone for prediction the gender in an Iranian population.

In our study, the mean of height in females and males was 156.4 cm and 170.6 cm; respectively. In the study conducted by Celbis O et.al in Turkey, the mean of height in females and males was 156.8 and 169.9 cm; respectively.⁶ In similar study performed on the fresh cadavers by Mall G et.al, it was reported 161 cm as a mean of height, and 156 and 168 cm for female and male; respectively.⁷ The mean of height for females and males in our study was similar to the above studies.

In this study, the least length of height was among the age group who were less than 20 years and the maximum length of height was among the age group between 20 and 39 years old. These differences were justified by undeveloped-bone growth for those younger than 20 years.

The higher rate of height among 20–39 years can be justified by several reasons including more bone density, the absence of skeletal diseases dependent to age such as osteoporosis and degenerative diseases of joints and variations related to age in intervertebral disks and other cartilages.

The least length of radius was among the aged group younger than 20 years, and the maximum length was between 20 and 39 years old, this lower rate for those younger than 20 years was justified by undeveloped-bone growth.

In this study, there was a statistical significant difference between the length of radius in males and females ($P = 0.00$). According to the above results and comparative the height and the

Table 2
Mean, SD, minimum & maximum of height length (cm) in different age group considering sex.

Height	Female				Male				Total			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Age Groups(yr)												
<20	148.44	16.18	124	169	163.73	11.73	139	181	156.85	15.6	124	181
20–39	159.63	3	154	166	174.53	5.61	159	183	168.58	8.76	154	183
40–64	157.5	4.46	148	162	170.63	6.72	159	180	165.55	8.75	148	180
≥65	157.5	5.83	149	169	167.86	5.49	159	174	162.33	7.65	149	174
Total	156.44	8.85	124	169	170.61	8/20	139	183	164.59	10.99	124	183

Table 3

Mean, S.D, minimum, maximum of radius length(cm) in different age groups considering sex.

Radius length Age group (yr)	Female				Male				Total			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max
<20	19.12	3.02	15.1	22.9	22.53	3.30	15.1	26.6	21.00	3.55	15.1	26.6
20–39	21.55	0.78	19.6	22.6	25.51	1.23	21.6	27.3	23.92	2.23	19.6	27.3
40–64	20.87	1.00	18.1	22.1	24.52	1.44	21.8	26.6	23.11	2.20	18.1	26.6
≥65	21.48	95.0	20.6	23.6	24.00	1.58	21.6	25.6	22.66	1.79	20.6	25.6
Total	20.87	1.77	15.1	23.6	24.49	2.10	15.1	27.3	22.95	2.65	15.1	27.3

Table 4

Sensitivity and specificity of demarking point (d.p) of radius in age groups.

Age group (yr)	^a d.p (cm)	Sensitivity	Specificity
<20	20.80	93.0%	34.0%
20–39	23.50	79.0%	98.0%
40–64	22.68	83.0%	96.0%
≥65	22.75	82.0%	96.0%
Total	22.70	83.0%	96.0%

^a d.p: demarking point.

length of radius in different age groups, all of the parameters were shorter in females than males. In the previous studies, the length of different bones of females was reported 94% of the same race in males.¹

In the study conducted by Van Riet RP et al, the mean of length of radius in fresh cadavers was reported 235 mm.⁸ Mall. G et al reported the maximum length of radius in males and females 24.6 and 22 cm; respectively. This difference of dimensions was remarkable between two gender ($P < 0.0005$).⁷ Holman et al, have also reported the length of radius in males and females 24.3 and 21.9 cm; respectively.⁹ The above mentioned-studies showed that our results were similar to previous studies.

In the study conducted by Celbis et al, the mean of the length of radius in males was 24.5 with a minimum of 21.7 and maximum of 27 cm, in females was 21.7 with a minimum of 19.2 and maximum of 24.1 cm.⁶ The mean of the length of radius and the maximum of that in both sexes were similar to the above studies but the minimum of the length of radius was lower than cases in the previous studies. This issue was not remarkable due to this fact that the minimum age was 10 years old in our study.

On the basis of the results of this study, the length of radius bone could be used in order to recognize the gender, this was raised from this fact that the radius bone with d.p of 22.7 cm has a sensitivity and specificity of 83% and 96%; respectively. But according to this study the rate of specificity among age group under 20 years was low, this fact was expected due to undeveloped-bone growth before adolescence. There was no published study regarding the demarking point in different age groups.

In the study conducted by Berrizibetia et al, the precision of gender determinant by using both radius bones was reported to be

96%.¹⁰ Mall G et al reported in their study that the precision of prediction of gender was estimated to be 89%.⁷

In a study conducted in Turkey by Celbis et al, the demarking point was estimated 23.5 cm which it's precision to determine the gender of male and female was 90% and 91.5%; respectively.⁶

In the study conducted by researchers on ulna bone, the sensitivity of 78% and specificity of 93% were reported.⁴ According to this study, the sensitivity and specificity of radius were higher than ulna to determine the gender. On the basis of certain previous studies, by using complete skeleton of body up to 100%, pelvis 95%, skull 92%, and long bone 80%, it will be possible for us to be assured regarding the reliability of gender determination,¹ which in this study the accuracy of radius for gender determination was higher.

In this study, we obtained some equations in order to determine the length of height by using the length of radius bone in different age groups in both sexes.

In spite of existence of general similarities between the equation of previous studies⁶ and our study, the existence of small differences could be due to the racial differences and range of age for whom were considered. As in this study, we obtained an equation for each age group and for both sexes, the precision of these equations could be more than other studies.

In this study the proportion of the length of radius to the length of ulna was considered and the mean of this ratio in both sexes was reported 97% ($P = 0.78$). In another words, with the ratio of R/U the gender could not be determined. In this regard, there was not the significant difference among different age groups. According to the search of the authors there was no study regarding the comparison of the obtained ratio in different races.

According to this fact that this study was conducted on the fresh cadavers, therefore in cases such as explosion, aerial accidents and etc, by using the length of radius, we could be able to determine the length of height and gender with high confidence. Also, regarding to the ratio of R/U in this study, it can help us in order to separate the bones and cadavers properly and estimate the minimum number of victims.

This research was done on fresh Iranian cadavers in Legal Medicine Organization. Legal Medicine Organization of Iran with more than 1.5 million clinical forensic referrals and 50 000 autopsies per year is an appropriate field for such researches and trainings.^{11,12}

Table 5

Calculation of the height using the radius length in different age groups according to sex.

Sex Age group (yr)	Male			Female		
	Height (cm)	R square	P value	Height (cm)	R square	P value
<20	$84.68 + [3.51 \times \text{R.L}]^a$	0.98	0.00	$48.36 + [5.23 \times \text{R.L}]^a$	0.96	0.00
20–39	$62.64 + [4.39 \times \text{R.L}]^a$	0.93	0.00	$100.81 + [2.73 \times \text{R.L}]^a$	0.50	0.02
40–64	$82.09 + [3.61 \times \text{R.L}]^a$	0.60	0.00	$173.06 - [0.75 \times \text{R.L}]^a$	0.03	0.60 (NS) ^b
≥65	$85.25 + [3.44 \times \text{R.L}]^a$	0.98	0.00	$40.99 + [5.42 \times \text{R.L}]^a$	0.79	0.003
Overall	$80.42 + [3.68 \times \text{R.L}]^a$	0.89	0.00	$65.59 + [4.35 \times \text{R.L}]^a$	0.76	0.00

^a R.L: Radius Length.^b NS: Non-Significant.

Table 6

Mean, S.D, minimum & maximum of radius/Ulna(R/U) ratio in different age groups in both sexes.

R/U Age group (yr)	Female				Male				Total			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max	Mean	S.D	Min	Max
< 20	0.95	0.020	0.94	0.96	0.96	0.026	94.0	0.98	0.95	0.024	0.94	0.97
20 – 39	0.96	0.029	0.95	0.98	0.78	0.034	95.0	0.98	0.97	0.032	0.95	0.98
40 – 64	0.99	0.053	0.95	1.02	1.02	0.039	95.0	0.98	0.97	0.045	0.96	0.99
≥65	0.98	0.023	0.94	1	1	0.043	94.0	1.01	0.98	0.033	0.96	0.99
total	0.97	0.037	0.96	0.98	0.97	0.035	96.0	0.97	0.97	0.036	0.96	0.97

Conflict of interest

We have no competing interests.

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Ethical approval

Written informed consent forms were completed by the close relatives of the deceased, and they were assured that all the secrets and information about the bodies were fully confidential. The ethical principles of the Helsinki Declaration were respected by the authors. The forms were signed by the relatives in all steps when the measurements of the lengths and widths were to be done.

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References

1. Knight B, Saukko P. *Knight's forensic pathology*. 3rd ed. UK: Arnold; 2004. pp. 106–117.
2. El-Najjar M, Mc Williams K. *Forensic anthropology*. 1st ed. USA: Charles C Thomas; 1978. p. 87.
3. Linda L, Klepinger R. *Fundamentals of forensic anthropology*. Hoboken New jersey: John Wiley & Sons, Inc.; 2006. p. 53.
4. Madden AM, Tsikoura T, stott DJ. The estimation of body height from ulnar length in adults from different ethnic groups. *J Hum Nutr Diet* 2008;**21**(4):394.
5. Gauld LM, Kappers carlin JB, Robertson CF. Height prediction from ulna length. *Dev Med Child Neurol* 2004;**46**(7):475–80.
6. Celbis O, Agritmis H. Estimation of stature and determination of sex from radial and ulnar bone length in a Turkish corpse sample. *Forensic Sci Int* 2006;**158**(2–3):135–9.
7. Mall G, Hubing M, Buttner A, Kuznik J, Penning R, Graw M. Sex determination and estimation of stature from the long bones of the arm. *Forensic Sci Int* 2001;**117**(1–2):23–30.
8. Van Riet RP, Van Glabbeek F, Neale PG, Bimmel R, Bortier H, Morrey BF, et al. Anatomical considerations of the radius. *Clin Anat* 2004;**17**(7):564–9.
9. Holman DJ, Bennett KA. Determination of sex from arm bone measurements. *Am J Phys Anthropol* 1991;**84**(4):421–6.
10. Berrizibeitia EL. Sex determination with the head of the radius. *J Forensic Sci* 1989;**34**(5):1206–13.
11. Akhlaghi M, Sheikhezadi A, Naghsh A, Dorvashi G. Identification of sex in Iranian population using patella dimensions. *J Forensic Leg Med* 2010;**17**(3):150–5.
12. Akhlaghi M, Sheikhezadi A, Khosravi N, Pournia Y, Sabery Anary SH. The value of the anthropometric parameters of the tibia in the forensic identification of the Iranian population over the age of 20. *J Forensic Med Pathol* 2011;**18**(6):257–63.